Part I
Getting Started

Chapter 4
Considering the Site

Contents

Considering the Site

This chapter will help you:

- *Become familiar with environmental, geological, and manmade features that influence siting decisions.*
- *Identify nearby areas or land uses that merit buffer zones and place your unit an appropriate distance from them.*
- *Comply with local land use and zoning restrictions, including any amendments occurring during consideration of potential sites.*
- *Understand existing environmental justice issues as you consider a new site.*
- *Avoid siting a unit in hydrologic or geologic problem areas, without first designing the unit to address conditions in those areas.*

Many hydrologic and geologic settings can be effectively utilized for protective waste management. There are, however, some hydrologic and geologic conditions that are best avoided all together if possible. If they cannot be avoided, special design and construction precautions can minimize risks. Floodplains, earthquake zones, unstable soils, and areas at risk for subsurface movement need to be taken into account just as they would be when siting and constructing a manufacturing plant or home. Catastrophic events associated with these locations could seriously damage or destroy a waste management unit, release contaminants into the environment, and add substantial expenses for cleanup, repair, or reconstruction. If problematic site conditions cannot be avoided, engineering design and construction techniques can address some of the concerns raised by locating a unit in these areas.

This chapter will help address the following questions:

- What types of sites need special consideration?
- How will I know whether my waste management unit is in an area requiring special consideration?
- Why should I be concerned about siting a waste management unit in such areas?
- What actions can I take if I plan to site a unit in these areas?

Many state, local, and tribal governments require buffer zones between waste management units and other nearby land uses. Even if buffer zones are not required, they can still provide benefits now and in the future. Buffer zones provide time and space to contain and remediate accidental releases before they reach sensitive environments or sensitive populations. Buffer zones also help maintain good community relations by reducing disruptions associated with noise, traffic, and wind-blown dust, often the source of serious neighborhood concerns.

In considering impacts on the surrounding community, it is important to understand whether the community, especially one with a large minority and low income population, already faces significant environmental impacts from existing industrial activities. You should develop an understanding of the community's current environmental problems and work together to develop plans that can improve and benefit the environment, the community, the state, and the company.

How should a waste management unit site assessment begin?

In considering whether to site a new waste management unit or laterally expand an existing unit, certain factors will influence the siting process. These factors include land availability, distance from waste generation points, ease of access, local climatic conditions, economics, environmental considerations, local zoning requirements, and potential impacts on the community. As prospective sites are identified, you should become familiar with the siting considerations raised in this chapter. Determine how to address concerns at each site to minimize a unit's adverse impacts on the environment in addition to the environment's adverse impacts on the unit. You should choose the site that best balances protection of human health and the environment with operational goals. In addition to considering the issues raised in this chapter, you should check with state and local regulatory agencies early in the siting process to identify other issues and applicable restrictions.

Another factor to consider is whether there are any previous or current contamination problems at the site. It is recommended that potential sites for new waste management units be free of any contamination problems. An environmental site assessment (ESA) may be required prior to the disturbance of any land area or before property titles are transferred. An ESA is the process of determining whether contamination is present on a parcel of property. You should check with the EPA regional office and state or local authorities to determine if there are any ESA requirements prior to siting a new unit or expanding an existing unit. If there are no requirements, you might want to consider performing an ESA in order to ensure that there are no contamination problems at the site.

Many companies specialize in site screening, characterization, and sampling of different environmental media (i.e., air, water, soil) for potential contamination. A basic ESA (often referred to as the Phase I Environmental Site Assessment process) typically involves researching prior land use, deciding if sampling of environmental media is necessary based on the prior activities, and determining contaminate fate and transport if contamination has occurred. Liability issues can arise if the site had contamination problems prior to construction or expansion of the waste management unit. Information on the extent of contamination is needed to quantify cleanup costs and determine the cleanup approach. Cleanup costs can represent an additional, possibly significant, project cost when siting a waste management unit.

As discussed later in this chapter, you will also need to consider other federal laws and regulations that could affect siting. For example, the Endangered Species Act (16 USC Sections 1531 et seq.) provides for the designation and protection of threatened or endangered wildlife, fish, and plant species, and ensures the conservation of the ecosystems on which such species depend. It is the responsibility of the facility manager to check with and obtain a Section 10 permit from the Secretary of the Interior if the construction or operation of a waste management unit might potentially impact any endangered or threatened species or its critical habitat. Thus, you might not be able to site a new waste management unit in an area where endangered or threatened species live, or expand an existing unit into such an area. As another example, the National Historic Preservation Act (16 USC Sections 470 et seq.) protects historic sites and archaeological resources. The facility manager of a waste management unit should be aware of the properties listed on the National Register of Historic Properties. The facility manager should consult with the state historic preservation office to ensure that the property to be used for a new unit or lateral expansion of an existing unit will not impact listed historic properties, or sites with archeological significance. Other federal laws or statutes might also require consideration. It is the ultimate responsibility of the facility owner or manager to comply with the requirements of all applicable federal and state statutes when siting a waste management unit.

Additional factors, such as proximity to other activities or sites that affect the environment, also might influence siting decisions. To determine your unit's proximity to other facilities or industrial sites, you can utilize EPA's Envirofacts Warehouse. The Envirofacts Web site at <**www.epa.gov/enviro/index_java.html**> provides users with access to several EPA databases that will provide you with information about various environmental activities including toxic chemical releases, water discharges, hazardous waste handling processes, Superfund status, and air releases. The Web site allows you to search one database or several databases at a time about a specific location or facility. You can also create maps that display environmental information using the "Enviromapper" application located at <**www.epa.gov/enviro/html/mod/index.html**>. Enviromapper allows users to map different types of environmental information, including the location of drinking water supplies, toxic and air releases, hazardous waste sites, water discharge permits, and Superfund sites at the national, state, and county levels.

EPA's Waste Management—Facility Siting Application is a powerful new Web-based tool that provides assistance in locating waste management facilities. The tool allows the user to enter a ZIP code; city and state; or latitude and longitude to identify the location of fault lines, flood planes, wetlands, and karst terrain in the selected area. The user also can use the tool to display other EPA regulated facilities, monitoring sites, water bodies, and community demographics. The Facility Siting Application can be found at <**www.epa.gov/epaoswer/non-hw/industd/index.htm**>.

I. General Siting Considerations

Examining the topography of a site is the first step in siting a unit. Topographic information is available from the U.S. Geological Survey (USGS), the Natural Resources Conservation Service (NRCS)[1], the state's geological survey office or environmental regulatory agency, or local colleges and universities. Remote sensing data or maps from these organizations can help you determine whether your prospective site is located in any of the areas of concern discussed in this section. USGS maps can be downloaded or ordered from their Web site at <**mapping.usgs.gov**>. Also, the University of Missouri-Rolla maintains a current list of state geological survey offices on its library's Web site at <**www.umr.edu/~library/geol/geoloff.html**>.

A. Floodplains

A floodplain is a relatively flat, lowland area adjoining inland and coastal waters. The

[1] This agency of the U.S. Department of Agriculture was formerly known as the Soil Conservation Service (SCS).

Flood waters overflowed from the Mississippi River (center) into its floodplain (foreground) at Quincy, Illinois in the 1993 floods that exceeded 100-year levels in parts of the Midwest.

100-year floodplain—the area susceptible to inundation during a large magnitude flood with a 1 percent chance of recurring in any given year—is usually the floodplain of concern for waste management units. You should determine whether a candidate site is in a 100-year floodplain. Siting a waste management unit in a 100-year floodplain increases the likelihood of floods inundating the unit, increases the potential for damage to liner systems and support components (e.g., leachate collection and removal systems or other unit structures), and presents operational concerns. This, in turn, creates environmental and human health and safety concerns, as well as legal liabilities. It can also be very costly to build a unit to withstand a 100-year flood without washout of waste or damage to the unit, or to reconstruct a unit after such a flood. Further, locating your unit in a floodplain can exacerbate the damaging effects of a flood, both upstream and downstream, by reducing the temporary water storage capacity of the floodplain. As such, it is preferable to locate potential sites outside the 100-year floodplain.

How is it determined if a prospective site is in a 100-year floodplain?

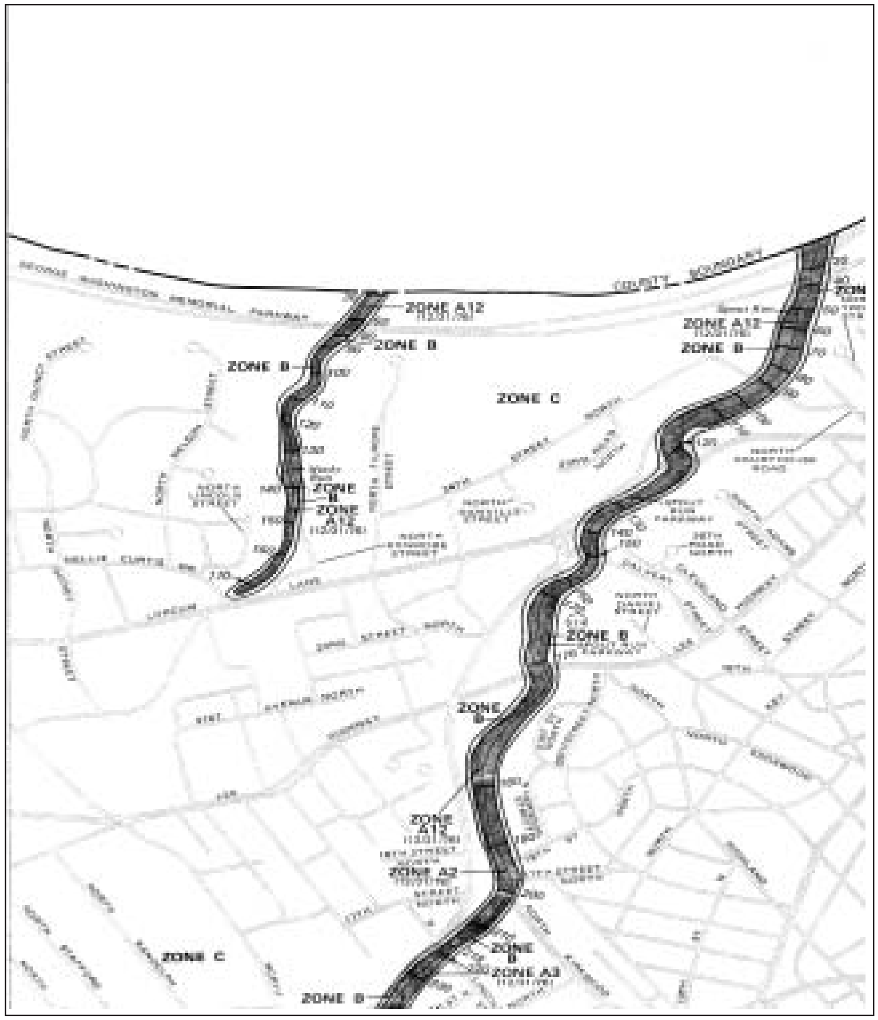
The first step in determining whether a prospective site is located in a 100-year floodplain is to consult with the Federal Emergency Management Agency (FEMA). FEMA has prepared flood hazard boundary maps for most regions. If a prospective site does not appear to be located in a floodplain, further exploration is not necessary. If uncertainty exists as to whether the prospective site might be in a floodplain, several sources of information are available to help make this determination. More detailed flood insurance rate maps (FIRMs) can be obtained from FEMA. FIRMs divide floodplain areas into three zones: A, B, and C. Class A zones are the most susceptible to flooding while class C zones are the least susceptible. FIRMs can be obtained from FEMA's Web site at **<msc.fema.gov/MSC/ hardcopy.htm>**.

Additional information can be found on flood insurance rate maps in FEMA's publication *How to Read a Flood Insurance Rate Map* (visit: **<www.fema.gov/nfip/ readmap.htm>**). FEMA also publishes *The National Flood Insurance Program Community Status Book* which lists communities with flood insurance rate maps or floodway maps. Floodplain maps can also be obtained through the US Geological Survey (USGS); National Resources Conservation Service (NRCS); the Bureau of Land Management; the Tennessee Valley Authority; and state, local, and tribal agencies.[2]

Note that river channels shown in floodplain maps can change due to hydropower or flood control projects. As a result, some floodplain boundaries might be inaccurate. If you suspect this to be the case, consult recent aerial photographs to determine how river channels have been modified.

[2] Copies of flood maps from FEMA are available at Map Service Center, P.O. Box 1038, Jessup, MD 20794-1038, by phone 800 358-9616, or the Internet at **<www.fema.gov/nfip/readmap.htm>**.

If maps cannot be obtained, and a potential site is suspected to be located in a floodplain, you can conduct a field study to delineate the floodplain and determine the floodplain's properties. To perform a delineation, you can draw on meteorological records and physiographic information, such as existing and planned watershed land use, topography, soils and geographic mapping, and aerial photographic interpretation of land forms. Additionally, you can use the U.S. Water Resources Council's methods of determining flood potential based on stream gauge records, or you can estimate the peak discharge to approximate the probability of exceeding the 100-year flood. Contact the USGS, Office of Surface Water, for additional information concerning these methods.[3]



FEMA provides flood maps like this one for most floodplains
Source: FEMA, Q3 Flood Data Users Guide **<www.fema.gov/msc>**.

What can be done if a prospective site is in a floodplain?

If a new waste management unit or lateral expansion will be sited in a floodplain, design the unit to prevent the washout of waste, avoid significant alteration of flood flow, and maintain the temporary storage capacity of the floodplain. Engineering models can be used to estimate a floodplain's storage capacity and floodwater flow velocity. The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center has developed several computer models for simulating flood properties.[4] The models can predict how a waste management unit sited in a floodplain can affect its storage capacity and can also simulate flood control structures and sediment transport. If a computer model predicts that placement of the waste management unit in the floodplain raises the base flood level by more than 1 foot, the unit might alter the storage capacity of the floodplain. If designing a new unit, you should site it to minimize these effects. The impact of your unit's location on the speed and flow of flood waters determines the likelihood of waste washout. To quantify this, estimate the shear stress on the unit's support components caused by the impinging flood waters at the depth, velocity,

[3] Information on stream gaging and flood forecasting can be obtained from the USGS, Office of Surface Water, at 413 National Center, Reston, VA 22092, by phone 703 648-5977, or the Internet at **<water.usgs.gov>**.

[4] The HEC-1, HEC-2, HEC-5, and HEC-6 software packages are available free of charge through the USACE Web site at **<http://www.hec.usace.army.mil/software/software_distrib/>**.

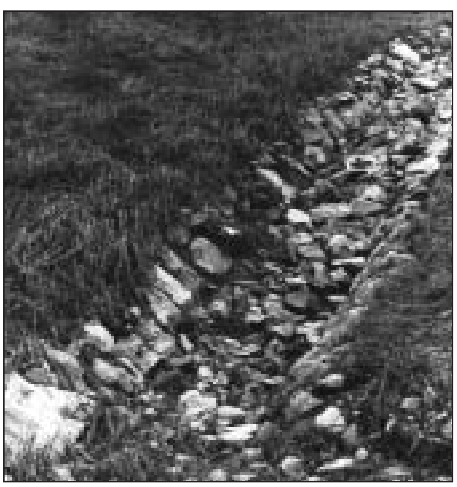
Knowing the behavior of waters at their peak flood level is important for determining whether waste will wash out.

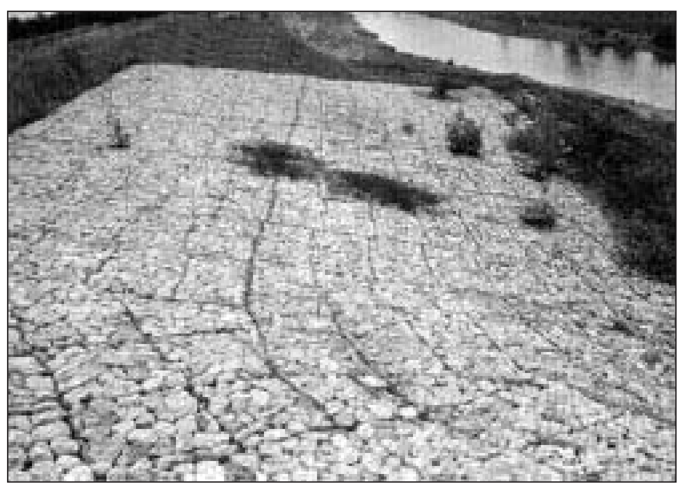
and duration associated with the peak (i.e., highest) flow period of the flood.

While these methods can help protect your unit from flood damage and washout, be aware that they can further contribute to a decrease in the water storage and flow capacity of the floodplain. This, in turn, can raise the level of flood waters not only in your area but in upstream and downstream locations, increasing the danger of flood damage and adding to the cost of flood control programs. Thus, serious consideration should be given to siting a waste management unit outside a 100-year floodplain.

B. Wetlands

Wetlands, which include swamps, marshes, and bogs, are vital and delicate ecosystems. They are among the most productive biological communities on earth and provide habitat for many plants and animals. The U.S. Fish and Wildlife Service estimates that up to 43 percent of all endangered or threatened species rely on wetlands for their survival.[5]





Riprap (rock cover) reduces stream channel erosion (left) and gabions (crushed rock encased in wire mesh) help stabilize erodible slopes (right).

Sources: U.S. Department of the Interior, Office of Surface Mining (left); The Construction Site—A Directory To The Construction Industry (right).

[5] From EPA's Wetlands Web site, Values and Functions of Wetlands factsheet, <**www.epa.gov/owow/wetlands/facts/fact2.html**>.

> For regulatory purposes under the Clean Water Act, wetlands are defined as areas "that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."
>
> 40 Code of Federal Regulations (CFR) 232.2(r)

Wetlands protect water quality by assimilating water pollutants, removing sediments containing heavy metals, and recharging groundwater supplies. Wetlands also prevent potentially extensive and costly floods by temporarily storing flood waters and reducing their velocity. These areas also offer numerous recreational opportunities.

Potential adverse impacts associated with locating your unit in a wetland include dewatering the wetland (i.e., causing removal or drainage of water), contaminating the wetland, and causing loss of wetland acreage. Damage could also be done to important wetland ecosystems by destroying their aesthetic qualities and diminishing wildlife breeding and feeding opportunities. Siting in a wetland increases the potential for damage to your unit, especially your liner system and structural components, as a result of ground settlement, action of the high water table, and flooding. Alternatives to siting a waste management unit in a wetland area should be given serious consideration based upon Section 404 requirements in the Clean Water Act (CWA) as discussed below.

If a waste management unit is to be sited in a wetland area, the unit will be subject to additional regulations. In particular, Section 404 of the Clean Water Act (CWA) authorizes the Secretary of the Army, acting through the Chief of Engineers, to issue permits for the discharge of dredged or fill material into wetlands and other waters of the United States.[6] Activities in waters of the United States regulated under this permitting program include "placement of fill material for construction or maintenance of any liner, berm, or other infrastructure associated with solid waste landfills," as well as fills for development, water resource projects, infrastructure improvements, and conversion of wetlands to uplands for farming and forestry (40 CFR Section 232.2—definition of "discharge of fill material"). EPA regulations under Section 404 (33 United States Code Section 1344) stipulates that no discharge of dredged or fill material can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if the nation's waters would be significantly degraded. Therefore, in

Different types of wetlands: spruce bog (left) and eco pond in the Florida Everglades (right).

[6] For the full text of the Clean Water Act, including Section 404, visit the U.S. House of Representatives Internet Law Library Web site at <**uscode.house.gov/download.htm**>, under Title 33, Chapter 26.

compliance with the guidelines established under Section 404, all permit applicants must:

- Take steps to avoid wetland impacts where practicable.
- Minimize impacts to wetlands where they are unavoidable.
- Compensate for any remaining, unavoidable impacts by restoring or creating wetlands.

The EPA and USACE jointly administer a review process to issue permits for regulated activities. For projects with potentially significant impacts, an individual permit is usually required. For most discharges with only minimal adverse effects, USACE may allow applicants to comply with existing general permits, which are issued on a nationwide, regional, or statewide basis for particular activity categories as a means to expedite the permitting process. In making permitting decisions, the agencies will consider other federal laws that might restrict placement of waste management units in wetlands. These include the Endangered Species Act; the Migratory Bird Conservation Act; the Coastal Zone Management Act; the Wild and Scenic Rivers Act; the Marine Protection, Research and Sanctuaries Act; and the National Historic Preservation Act.

How is it determined if a prospective site is in a wetland?

As a first step, determine if the prospective site meets the definition of a wetland. If the prospective site does not appear to be a wetland, then no further exploration is necessary. If it is uncertain whether the prospective site is a wetland, then several sources are available to help you make this determination and define the boundaries of the wetland. Although this can be a challenging process, it will help you avoid future liability since filling a wetland without the appropriate federal, state, or local permits would be a violation of many laws. It might be possible to learn the extent of wetlands without performing a new delineation, since many wetlands have previously been mapped. The first step, therefore, should be to determine whether wetlands information is available for your area.

At the federal level, four agencies are principally involved with wetlands identification and delineation: USACE, EPA, the U.S. Fish and Wildlife Service (FWS), and National Resource Conservation Service (NRCS). EPA also has a Wetlands Information Hotline (800 832-7828) and a wetlands Web site at **<www.epa.gov/owow/wetlands>** which provides information about EPA's wetlands program; facts about wetlands; the laws, regulations, and guidance affecting wetlands; and science, education, and information resources for wetlands. The local offices of NRCS (in agricultural areas) or regional USACE Engineer Divisions and Districts **<www.usace.army.mil/divdistmap.html>** might know whether wetlands in the vicinity of the potential site have already been delineated.

Additionally, FWS maintains the National Wetlands Inventory (NWI) Center,[7] from which you can obtain wetlands mapping for much of the United States. This mapping, however, is based on aerial photography, which is not reliable for specific field determinations. If you have recently purchased your site, you also might be able to find out from the previous property owner whether any delineation has been completed that might not be on file with these agencies. Even if existing delineation information for the site is found, it might still be prudent to contact a qualified wetlands consultant to verify the wetland boundaries, especially if the delineation is not a field determination or is more than a few years old.

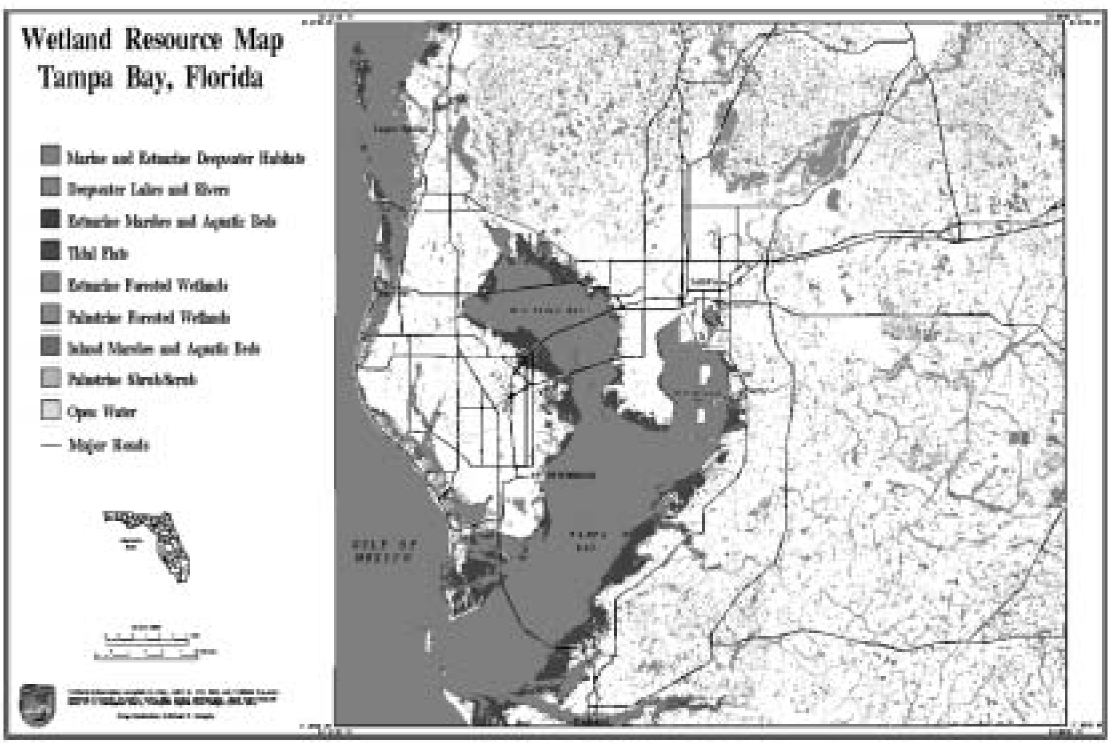
If the existence of a wetland is uncertain, you should obtain a wetlands delineation.

[7] To contact NWI, write to National Wetlands Inventory Center, 9720 Executive Center Drive, Suite 101, Monroe Building, St. Petersburg, FL 33702, call 727 570-5400, or fax 727 570-5420. For additional information online or to search for maps of your area, visit: **<www.nwi.fws.gov>**.

This procedure should be performed only by an individual with experience in performing a wetlands delineation[8] using standard delineation procedures or applicable state or local delineation standards. The delineation procedure, with which you should become familiar before hiring a delineator, involves collecting maps, aerial photographs, plant data, soil surveys, stream gauge data, land use data, and other information. Note that it is mandatory that wetlands delineation for CWA Section 404 permitting purposes be conducted in accordance with the 1987 *U.S. Army Corps of Engineers Wetlands Delineation Manual*[9] (USACE, 1991). The manual provides guidelines and methods for determining whether an area is a wetland for purposes of Section 404. A three-parameter approach for assessing the presence and location of hydrophytic vegetation (i.e., plants that are adapted for life in saturated soils), wetland hydrology, and hydric soils is discussed.

What can be done if a prospective site is in a wetland?

Before constructing a waste management unit in a wetland area, consider whether you can locate the unit elsewhere. If an alternative location can be identified, strongly consider pursuing such an option, as required by Section 404 of the CWA. Because wetlands are important ecosystems that should be protected, identification of practicable location alternatives is a necessary first step in the siting process. Even if no viable alternative loca-



NWI wetland resource maps like this one show the locations of various different types of wetlands and are available for many areas.

Source: NWI web site, sample GIS Think Tank maps page, **<wetlands.fws.gov/>**.

[8] Currently, there is no federal certification program. In March 1995, USACE proposed standards for a Wetlands Delineator Certification Program (WDCP), but the standards have not been finalized. If the WDCP standards are finalized and implemented, you should use WDCP-certified wetland consultants.

[9] The 1987 manual can be ordered from the National Technical Information Service (NTIS) at 703 605-6000 or obtained online at <**www.wes.army.mil/el/wetlands/wlpubs.html**>.

tions are identified, it might be beneficial to keep a record of the alternatives investigated, noting why they were not acceptable. Such records might be useful during the interaction between facilities, states, and members of the community.

If no alternatives are available, you should consult with state and local regulatory agencies concerning wetland permits. Most states operate permitting programs under the CWA, and state authorities can guide you through the permitting process. To obtain a permit, the state might require that the unit facility manager assess wetland impacts and then:

- Prevent contamination from leachate and runoff.
- Minimize dewatering effects.
- Reduce the loss of wetland acreage.
- Protect the waste management unit against settling.

C. Active Fault Areas

Faults occur when stresses in a geologic material exceed its ability to withstand these forces. Areas surrounding faults are subject to earthquakes and ground failures, such as landslides or soil liquefaction. Fault movement can directly weaken or destroy structures, or seismic activity associated with faulting can cause damage to structures through vibrations. Structural damage to the waste management unit could result in the release of contaminants. In addition, fault movement might create avenues to groundwater supplies, increasing the risk of groundwater contamination.

Liquefaction is another common problem encountered in areas of seismic activity. The vibrating motions caused by an earthquake tend to rearrange the sand grains in soils. If the grains are saturated, the saturated granular material turns into a viscous fluid, a process referred to as liquefaction. This diminishes the bearing capacity of the soils and can lead to foundation and slope failures.

To avoid these hazards, do not build or expand a unit within 200 feet of an active fault. If it is not possible to site a unit more than 200 feet from an active fault, you should design the unit to withstand the potential ground movement associated with the fault area. A fault is considered active if there has been movement along it within the last 10,000 to 12,000 years.

How is it determined if a prospective site is in a fault area?

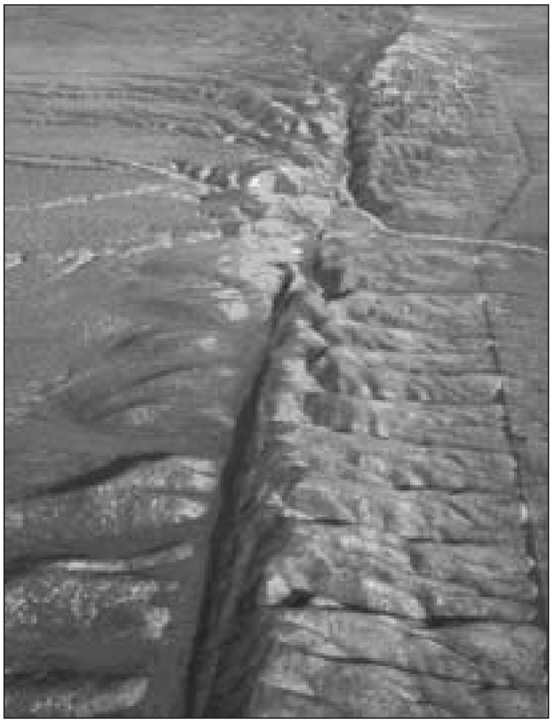
A series of USGS maps, Preliminary Young Fault Maps, Miscellaneous Field Investigation 916, identifies active faults.[10] These maps, however, might not be completely accurate due to recent shifts in fault lines. If a prospective site is well outside the 200 foot area of concern, no fault area considerations exist. If it is unclear how close a prospective site is to an active fault, further evaluation will be necessary. A geologic reconnaissance of the site and surrounding areas can be useful in verifying that active faults do not exist at the site.

If a prospective site is in an area known or suspected to be prone to faulting, you should conduct a fault characterization to determine if the site is near a fault. A characterization includes identifying linear features that suggest the presence of faults within a 3,000-foot radius of the site. Such features might be shown or described on maps, aerial photographs,[11] logs, reports, scientific literature, or insurance claim reports, or identified by a detailed field reconnaissance of the area.

If the characterization study reveals faults within 3,000 feet of the proposed unit or lat-

[10] Information about ordering these maps is available by calling 888 ASK-USGS or 703 648-6045.

[11] The National Aerial Photographic Program (NAPP) and the National High Altitude Program (NHAP), both administered by USGS, are sources of aerial photographs. To order from USGS, call 605 594-6151. For more information, see **<edc.usgs.gov/nappmap.html>**. Local aerial photography firms and surveyors are also good sources of information.



In this aerial view, the infamous San Andreas fault slices through the Carrizo Plain east of San Luis Obispo, California.

Source: USGS.

eral expansion, you should conduct further investigations to determine whether any of the faults are active within 200 feet of the unit. These investigations can involve drilling and trenching the subsurface to locate fault zones and evidence of faulting. Perpendicular trenching should be used on any fault within 200 feet of the proposed unit to examine the seismic epicenter for indications of recent movement.

What can be done if a prospective site is in a fault area?

If an active fault exists on the site where the unit is planned, consider placing the unit 200 feet back from the fault area. Even with such setbacks, only place a unit in a fault area if it is possible to ensure that no damage to the unit's structural integrity would result. A setback of less than 200 feet might be adequate if ground movement would not damage the unit.

If a lateral expansion or a new unit will be located in an area susceptible to seismic activity, there are two particularly important issues to consider: horizontal acceleration and movement affecting side slopes. Horizontal acceleration becomes a concern when a location analysis reveals that the site is in a zone with a risk of horizontal acceleration in the range of 0.1 g to 0.75 g (g = acceleration of gravity). In these zones, the unit design should incorporate measures to protect the unit from potential ground shifts. To address side slope concerns, you should conduct a seismic stability analysis to determine the most effective materials and gradients for protecting the unit's slopes from any seismic instabilities. Also, design the unit to withstand the impact of vertical accelerations.

If the unit is in an area susceptible to liquefaction, you should consider ground improvement measures. These measures include grouting, dewatering, heavy tamping, and excavation. See Table 1 for examples of techniques that are currently used.

Additional engineering options for fault areas include the use of flexible pipes for runoff and leachate collection, and redundant containment systems. In the event of foundation soil collapse or heavy shifting, flexible runoff and leachate collection pipes—along with a bedding of gravel or permeable material—can absorb some of the shifting-related stress to which the pipes are subjected. Also consider a secondary containment measure, such as an additional liner system. In earthquake-like conditions, a redundancy of this nature might be necessary to prevent contamination of the surrounding area if the primary liner system fails.

Table 1
Examples of Improvement Techniques for Liquefiable Soil Foundation Conditions

Method	Principle	Most Suitable Soil Conditions/Types	Applications
Blasting	Shock waves and vibrations cause limited liquefaction, displacement, remolding, and settlement to higher density.	Saturated, clean sands; partly saturated sands and silts after flooding.	Induce liquefaction in controlled and limited stages and increase relative density to potentially nonliquefiable range.
Vibrocompaction	Densification by vibration and compaction of backfill material of sand or gravel.	Cohesionless soils with less than 20 percent fines.	Induce liquefaction in controlled and limited stages and increase relative density to nonliquefiable condition. The dense column of backfill provides (a) vertical support, (b) drainage to relieve pore water pressure, and (c) shear resistance in horizontal and inclined directions. Used to stabilize slopes and strengthen potential failure surfaces.
Compaction piles	Densification by displacement of pile volume and by vibration during driving; increase in lateral effective earth pressure.	Loose sandy soils; partly saturated clayey soils; loess.	Useful in soils with fines. Increases relative density to nonliquefiable condition. Provides shear resistance in horizontal and inclined directions. Used to stabilize slopes and strengthen potential failure surfaces.
Displacement and compaction grout	Highly viscous grout acts as radial hydraulic jack when pumped in under high pressure.	All soils.	Increase in soil relative density and horizontal effective stress. Reduce liquefaction potential. Stabilize the ground against movement.
Mix-in-place piles and walls	Lime, cement, or asphalt introduced through rotating auger or special in-place mixer.	Sand, silts, and clays; all soft or loose inorganic soils.	Slope stabilization by providing shear resistance in horizontal and inclined directions, which strengthens potential failure surfaces or slip circles. A wall could be used to confine an area of liquefiable soil.
Heavy tamping (dynamic compaction)	Repeated application of high- intensity impacts at surface.	Cohesionless soils best; other types can also be improved.	Suitable for some soils with fines; usable above and below water. In cohesionless soils, induces liquefaction in controlled and limited stages and increases relative density to potentially nonliquefiable range.

Source: RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities. (EPA, 1995c).

D. Seismic Impact Zones

A seismic impact zone is an area having a 2 percent or greater probability that the maximum horizontal acceleration caused by an earthquake at the site will exceed 0.1 g in 50 years. This seismic activity can damage leachate collection and removal systems, leak detection systems, or other unit structures through excessive bending, shearing, tension, and compression. If a unit's structural components fail, leachate can contaminate surrounding areas. Therefore, for safety reasons, it is recommended that a unit not be located in a seismic impact zone. If a unit must be sited in a seismic impact zone, the unit should be designed to withstand earthquake-related hazards, such as landslides, slope failures, soil compaction, ground subsidence, and soil liquefaction.

Additionally, if you build a unit in a seismic impact zone, avoid rock and soil types that are especially vulnerable to earthquake shocks. These include very steep slopes of weak, fractured, and brittle rock or unsaturated loess,[12] which are vulnerable to transient shocks caused by tensional faulting. Avoid

[12] Loess is a wind-deposited, moisture-deficient silt that tends to compact when wet.

loess and saturated sand as well, because seismic shocks can liquefy them, causing sudden collapse of structures. Similar effects are possible in sensitive cohesive soils when natural moisture exceeds the soil's liquid limit. For a discussion of liquid limits, refer to the "Soil Properties" discussion in Chapter 7, Section B – Designing and Installing Liners. Earthquake-induced ground vibrations can also compact loose granular soils. This could result in large uniform or differential settlements at the ground surface.

How is it determined if a prospective site is in a seismic impact zone?

If a prospective site is in an area with no history of earthquakes, then seismic impact zone considerations might not exist. If it is unclear whether the area has a history of seismic activity, then further evaluation will be necessary. As a first step, consult the USGS field study map series MF-2120, *Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico*.[13] These maps provide state- and county-specific information about seismic impact zones. Additional information is available from the USGS National Earthquake Information Center (NEIC),[14] which maintains a database of known earthquake and fault zones. Further information concerning the USGS National Seismic Hazard Mapping Project can be accessed at <**geohazards.cr.usgs.gov/eq**>. USGS's Web site also allows you to find ground motion hazard parameters (including peak ground acceleration and spectra acceleration) for your site by entering a 5 digit ZIP code <**eqint.cr.usgs.gov/eq/html/zipcode.shtml**>, or a latitude-longitude coordinate pair <**eqint.cr.usgs.gov/eq/html/lookup.shtml**>. The USGS Web site explains how these values can be used to determine the probability of excedance for a particular level of ground motion at your site. This can help you determine if the structural integrity of the unit is susceptible to damage from ground motion.

For waste management unit siting purposes, use USGS' recently revised *Peak Acceleration (%g) with 2 % Probability of Exceedance in 50 Years* maps available at <**geohazards.cr.usgs.gov/eq/hazmapsdoc/junecover.html**>. It is important to note that ground motion values having a 2 percent probability of exceedance in 50 years are approximately the same as those having 10 percent probability of being exceeded in 250 years. According to USGS calculations, the annual exceedance probabilities of these two differ by about 4 percent (for a more complete discussion visit: <**geohazards.cr.usgs.gov/eq/faq/parm08.html**>).

If a site is or might be in a seismic impact zone, it is useful to analyze the effects of seismic activity on soils in and under the unit. Computer software programs are available that can evaluate soil liquefaction potential (defined in Section C of this chapter). LIQUFAC, a software program developed by the Naval Facilities Engineering Command in Washington, DC, can calculate safety factors for each soil layer in a given soil profile and the corresponding one dimensional settlements due to earthquake loading.

What can be done if a prospective site is in a seismic impact zone?

If a waste management unit cannot be sited outside a seismic impact zone, structural components of the unit—including liners, leachate collection and removal systems, and surface-water control systems—should be designed to resist the earthquake-related stresses expected in the local soil. You should consult professionals experienced in seismic analysis and

[13] For information on ordering these maps, call 888 ASK-USGS, write to USGS Information Services, Box 25286, Denver, CO 80225, or fax 303 202-4693. Online information is available at <**ask.usgs.gov/products.html**>.

[14] To contact NEIC, call 303 273-8500, write to United States Geological Survey, National Earthquake Information Center, Box 25046, DFC, MS 967, Denver, CO 80225, fax 303 273-8450, or e-mail sedas@neic.cr.usgs.gov. For online information, visit: <**neic.usgs.gov**>.

design to ensure that your unit is designed appropriately. To determine the potential effects of seismic activity on a structure, the seismic design specialist should evaluate soil behavior with respect to earthquake intensity. This evaluation should account for soil strength, degree of compaction, sorting (organization of the soil particles), saturation, and peak acceleration of the potential earthquake.

After conducting an evaluation of soil behavior, choose appropriate earthquake protection measures. These might include shallower slopes, dike and runoff control designs using conservative safety factors, and contingency plans or backup systems for leachate collection if primary systems are disrupted. Unit components should be able to withstand the additional forces imposed by an earthquake within acceptable margins of safety.

Additionally, well-compacted, cohesionless embankments or reasonably flat slopes in insensitive clay (clay that maintains its compression strength when remolded) are less likely to fail under moderate seismic shocks (up to 0.15 g - 0.20 g). Embankments made of insensitive, cohesive soils founded on cohesive soils or rock can withstand even greater seismic shocks. For earthen embankments in seismic regions, consider designing the unit with internal drainage and core materials resistant to fracturing. Also, prior to or during unit construction in a seismic impact zone, you should evaluate excavation slope stability to determine the appropriate grade of slopes to minimize potential slip.

For landfills and waste piles, using shallower waste side slopes is recommended, as steep slopes are more vulnerable to slides and collapse during earthquakes. Use fill sequencing techniques that avoid concentrating waste in one area of the unit for an extended period of time. This prevents waste pile side slopes from becoming too steep and unstable and alleviates differential loading of the foundation components. Placing too much waste in one area of the unit can lead to catastrophic shifting during an earthquake or heavy seismic activity. Shifting of this nature can cause failure of crucial system components or of the unit in general.

In addition, seismic impact zones have design issues in common with fault areas, especially concerning soil liquefaction and earthquake-related stresses. To address liquefaction, consider employing the soil improvement techniques described in Table 1. Treating liquefiable soils in the vicinity of the unit will improve foundation stability and help prevent uneven settling or possible collapse of heavily saturated soils underneath or near the unit.

To protect against earthquake-related stresses, consider installing redundant liners and special leachate collection and removal system components, such as secondary liner systems, composite liners, and leak detection systems combined with a low permeability soil layer. These measures function as backups to the primary containment and collection systems and provide a greater margin of safety for units during possible seismic stresses. Examples of special leachate systems include high-strength, flexible materials for leachate containment systems; geomembrane liner systems underlying leachate containment systems; and perforated polyvinyl chloride or high-density polyethylene piping in a bed of gravel or other permeable material.

E. Unstable Areas

Siting in unstable areas should be avoided because these locations are susceptible to naturally occurring or human-induced events or forces capable of impairing the integrity of a waste management unit. Naturally occurring unstable areas include regions with poor soil foundations, regions susceptible to mass movement, or regions containing karst terrain, which can include hidden sinkholes. Unstable areas caused by human activity can include areas near cut or fill slopes, areas with excessive drawdown of ground water, and areas where significant quantities of oil or natural gas have been extracted. If it is necessary to site a waste management unit in an unstable area, technical and construction techniques should be considered to mitigate against potential damage.

The three primary types of failure that can occur in an unstable area are settlement, loss of bearing strength, and sinkhole collapse. Settlement can result from soil compression if your unit is, or will be located in, an unstable area over a thick, extensive clay layer. The unit's weight can force water from the compressible clay, compacting it and allowing the unit to settle. Settlement can increase as waste volume increases and can result in structural failure of the unit if it was not properly engineered. Settlement beneath a waste management unit should be assessed and compared to the elongation strength and flexibility properties of the liner and leachate collection pipe system. Even small amounts of settlement can seriously damage leachate collection piping and sumps. A unit should be engineered to minimize the impacts of settlement if it is, or will be in an unstable area.

Loss of bearing strength is a failure mode that occurs in soils that tend to expand and rapidly settle or liquefy. Soil contractions and expansions can increase the risk of leachate or waste release. Another example of loss of bearing strength occurs when excavation near the unit reduces the mass of soil at the toe of the slope, thereby reducing the overall strength (resisting force) of the foundation soil.

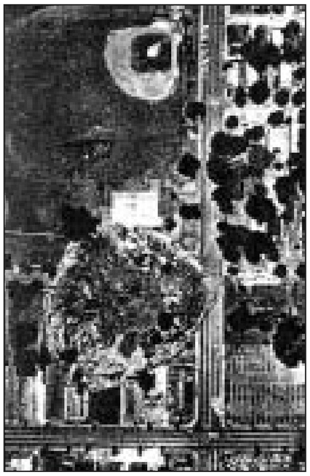
Catastrophic collapse in the form of sinkholes can occur in karst terrain. As water, especially acidic water, percolates through limestone, the soluble carbonate material dissolves, leaving cavities and caverns. Land overlying caverns can collapse suddenly, resulting in sinkholes that can be more than 100 feet deep and 300 feet wide.

How is it determined if a prospective site is in an unstable area?

If a stability assessment has not been performed on a potential site, you should have a qualified professional conduct one before designing a waste management unit on the prospective site. The qualified professional should assess natural conditions, such as soil geology and geomorphology, as well as human-induced surface and subsurface features or events that could cause differential ground settlement. Naturally unstable conditions can become more unpredictable and destructive if amplified by human-induced changes to the environment. If a unit is to be built at an assessed site that exhibits stability problems, tailor the design to account for any instability detected. A stability assessment typically includes the following steps:

Screen for expansive soils. Expansive soils can lose their ability to support a foundation when subjected to certain natural or human-induced events, such as heavy rain or explosions. Expansive soils usually are clay-rich and, because of their molecular structure, tend to swell and shrink by taking up and releasing water. Such soils include smectite (montmorillonite group) and vermiculite clays. In addition, soils rich in white alkali (sodium sulfate), anhydrite (calcium sulfate), or pyrite (iron sulfide) can also swell as water content increases. These soils are more common in the arid western states.

Check for soil subsidence. Soils subject to rapid subsidence include loesses, unconsolidated clays, and wetland soils. Unconsolidated clays can undergo considerable compaction when oil or water is removed. Similarly, wetland soils, which by their



Sinkholes, like this one that occurred just north of Orlando, Florida in 1981, are a risk of development in Karst terrain. Left: aerial view (note baseball diamond for scale); right: ground-level view. Photos courtesy of City of Winter Park, Florida public relations office.

nature are water-bearing, are also subject to subsidence when water is withdrawn.

Look for areas subject to mass movement or slippage. Such areas are often situated on slopes and tend to have rock or soil conditions conducive to downhill sliding. Examples of mass movements include avalanches, landslides, and rock slides. Some sites might require cutting or filling slopes during construction. Such activities can cause existing soil or rock to slip.

Search for karst terrain. Karst features are areas containing soluble bedrock, such as limestone or dolomite, that have been dissolved and eroded by water, leaving characteristic physiographic features including sinkholes, sinking streams, caves, large springs, and blind valleys. The principal concern with karst terrains is progressive or catastrophic subsurface failure due to the presence of sinkholes, solution cavities, and subterranean caverns. Karst features can also hamper detection and control of leachate, which can move rapidly through hidden conduits beneath the unit. Karst maps, such as *Engineering Aspects of Karst, Scale 1:7,500,000, Map No. 38077-AW-NA-07M-00,* produced by the USGS[15] and state specific geological maps can be reviewed to identify karst areas.

Scan for evidence of excessive groundwater drawdown or oil and gas extraction. Removing underground water can increase the effective overburden on the foundation soils underneath the unit. Excessive drawdown of water might cause settlement or bearing capacity failure on the foundation soils. Extraction of oil or natural gas can have similar effects.

Subsidence, slippage, and other kinds of slope failure can damage structures.

Investigate the geotechnical and geological characteristics of the site. It is important to establish soil strengths and other engineering properties. A geotechnical engineering con-

15 For information on ordering this map, call 888 ASK-USGS, write USGS Information Services, Box 25286, Denver, CO 80255, or fax 303 202-4693. Online information is available at **<www-atlas.usgs.gov/atlasmap.html>**.

sultant can accomplish this by performing standard penetration tests, field vane shear tests, and laboratory tests. This information will determine how large a unit you can safely place on the site. Other soil properties to examine include water content, shear strength, plasticity, and grain size distribution.

Examine the liquefaction potential. It is extremely important to ascertain the liquefaction potential of embankments, slopes, and foundation soils. Refer to Section C of this chapter for more information about liquefiable soils.

What can be done if a prospective site is in an unstable area?

It is advisable not to locate or expand your waste management unit in an unstable area. If your unit is or will be located in such an area, you should safeguard the structural integrity of the unit by incorporating appropriate measures into the design. The integrity of the unit might be jeopardized if this is not done.

For example, to safeguard the structural integrity of side slopes in an unstable area, reduce slope height, flatten slope angle, excavate a bench in the upper portion of the slope, or buttress slopes with compacted earth or rock fill. Alternatively, build retaining structures, such as retaining walls or slabs and piles. Other approaches include the use of geotextiles and geogrids to provide additional strength, wick and toe drains to relieve excess pore pressures, grouting, and vacuum and wellpoint pumping to lower ground- water levels. In addition, surface drainage can be controlled to decrease infiltration, thereby reducing the potential for mud and debris slides.

Additional engineering concerns arise in the case of waste management units in areas containing karst terrain. The principal concern with karst terrains is progressive or catastrophic subsurface failure due to the presence of sinkholes, solution cavities, and subterranean caverns. Extensive subsurface characterization studies should be completed before designing and building in these areas. Subsurface drilling, sinkhole monitoring, and geophysical testing are direct means that can be used to characterize a site. Geophysical techniques include electromagnetic conductivity, seismic refraction, ground-penetrating radar, and electrical resistivity (see the box below for more information). More than one technique should be used to confirm and correlate findings and anomalies, and a qualified geophysicist should interpret the results of these investigations.

Remote sensing techniques, such as aerial photograph interpretation, can also provide additional information on karst terrains. Surface mapping can help provide an understanding of structural patterns and relationships in karst terrains. An understanding of local carbonate geology and stratigraphy can help with the interpretation of both remote sensing and geophysical data.

You should incorporate adequate engineering controls into any waste management unit located in a karst terrain. In areas where karst development is minor, loose soils overlying the limestone can be excavated or heavily compacted to achieve the needed stability. Similarly, in areas where the karst voids are relatively small, the voids can be filled with slurry cement grout or other material.

Engineering solutions can compensate for the weak geologic structures by providing ground supports. For example, ground modifications, such as grouting or reinforced raft foundations, could compensate for a lack of ground strength in some karst areas. Raft constructions, which are floating foundations consisting of a concrete footing extending over a very large area, reduce and evenly distribute waste loads where soils have a low bearing capacity or where soil conditions are variable and erratic. Note, however, that raft foundations might not always prevent the

Geophysical Techniques

Electromagnetic Conductivity or Electromagnetic Induction (EMI). A transmitter coil generates an electromagnetic field which induces eddy currents in the earth located below the transmitter. These eddy currents create secondary electromagnetic fields which are measured by a receiver coil. The receiver coil produces an output voltage that can be related to subsurface conductivity variations. Analysis of these variations allows users to map subsurface features, stratigraphic profiles, and the existence of buried objects.

Seismic Refraction. An artificial seismic source (e.g., hammer, explosives) creates compression waves that are refracted as they travel along geologic boundaries. These refracted waves are detected by electromechanical transducers (geophones) which are attached to a seismograph that records the time of arrival of all waves (refracted and non-refracted). These travel times are compared and analyzed to identify the number of stratigraphic layers and the depth of each layer.

Ground-Penetrating Radar. A transmitting antenna dragged along the surface of the ground radiates short pulses of high-frequency radio waves into the ground. Subsurface structures reflect these waves which are recorded by a receiving antenna. The variations in reflected return signals are used to generate an image or map of the subsurface structure.

Electrical Resistivity. An electrical current is injected into the ground by a pair of surface electrodes (called the current electrodes). By measuring the resulting voltage (potential field) between a second pair of electrodes (called the potential electrodes), the resistivity of subsurface materials is measured. The measured resistivity is then compared to known values for different soil and rock types. Increasing the distance between the two pairs of electrodes increases the depth of measurement.

extreme collapse and settlement that can occur in karst areas. In addition, due to the unpredictable and catastrophic nature of ground failure in unstable areas, the construction of raft foundations and other ground modifications tends to be complex and can be costly, depending on the size of the area.

F. Airport Vicinities

The vicinity of an airport includes not only the facility itself, but also large reserved open areas beyond the ends of runways. If a unit is intended to be sited near an airport, there are particular issues that take on added importance in such areas. You should familiarize yourself with Federal Aviation Administration (FAA) regulations and guidelines. The primary concern associated with waste management units near airports is the hazard posed to aircraft by birds, which often feed at units managing putrescible waste. Planes can lose propulsion when birds are sucked into jet engines, and can sustain other damage in collisions with birds. Industrial waste management units that do not receive putrescible wastes should not have a problem with birds. Another area of concern for landfills and waste piles near airports is the height of the accumulated waste. If you own or operate such a unit, you should exercise caution when managing waste above ground level.

How is it determined if a prospective site will be located too close to an airport?

If the prospective site is not located near any airports, additional evaluation is not necessary. If there is uncertainty whether the prospective site is located near an airport, obtain local maps of the area using the various Internet resources previously discussed or from state and local regulatory agencies to identify any nearby public-use airports.

Topographic maps available from USGS are also suitable for determining airport locations. If necessary, FAA can provide information on the location of all public-use airports. In accordance with FAA guidance, if a new unit or an expansion of an existing unit will be within 5 miles of the end of a public-use airport runway, the affected airport and the regional FAA office should be notified to provide them an opportunity for review and comment.

What can be done if a prospective site is in an airport vicinity?

If a proposed waste management unit or a lateral expansion is to be located within 10,000 feet of an airport used by jet aircraft or within 5,000 feet of an airport used only by piston-type aircraft, design and operate your unit so it does not pose a bird hazard to aircraft. For above-ground units, design and operate your unit so it does not interfere with flight patterns. If it appears that height is a potential concern, consider entrenching the unit or choosing a site outside the airport's flight patterns. Most nonhazardous industrial waste management units do not usually manage wastes that are attractive food sources for birds, but if your unit handles waste that potentially attracts birds, take precautions to prevent birds from becoming an aircraft hazard. Discourage congregation of birds near your unit by preventing water from collecting on site; eliminating or covering wastes that might serve as a source of food; using visual deterrents, including realistic models of the expected scavenger birds' natural predators; employing sound deterrents, such as cannon sounds, distress calls of scavenger birds, or the sounds of the birds' natural predators; removing nesting and roosting areas (unless such removal is prohibited by the Endangered Species Act); or constructing physical barriers, such as a canopy of fine wires or nets strung around the disposal and storage areas when practical or technically feasible.

G. Wellhead Protection Areas

Wellhead protection involves protecting the ground-water resources that supply public drinking water systems. A wellhead protection area (WHPA) is the area most susceptible to contamination surrounding a wellhead. WHPAs are designated and often regulated to prevent public drinking water sources from becoming contaminated. The technical definition, delineation, and regulation of WHPAs vary from state to state. You should contact your state or local regulatory agency to determine what wellhead protection measures are in place near prospective sites. Section II of this chapter provides examples of how some states specify minimum allowable distances between waste management units and public water supplies, as well as drinking water wells. Locating a waste management unit in a WHPA can create a potential avenue for drinking water contamination through accidental release of leachate, contaminated runoff, or waste. In addition, some states might have additional restrictions for areas in designated "sole source aquifier" systems.

How is it determined if a prospective site is in a wellhead protection area?

A list of state wellhead protection program contacts is available on EPA's Web site at **<www.epa.gov/ogwdw/safewater/source/contacts.html>**. Also, USGS, NRCS, local water authorities, and universities can provide maps and further expertise that can help you to identify WHPAs. If there is uncertainty regarding the proximity of the prospective site to a WHPA, contact the appropriate state or local regulatory agency.

What can be done if a prospective site is in a wellhead protection area?

If a new waste management unit or lateral expansion will be located in a WHPA or suspected WHPA, consider design modifications to help prevent any ground-water contamination. For waste management units placed in these areas, work with state regulatory agencies to ensure that appropriate ground-water barriers are installed between the unit and the ground-water table. These barriers should be designed using materials of extremely low permeability, such as geomembrane liners or low permeability soil liners. The purpose of such barriers is to prevent any waste, or leachate that has percolated through the waste, from reaching the ground water and possibly affecting the public drinking water source.

In addition to ground-water barriers, the use of leachate collection, leak detection, and runoff control systems should also be considered. Leachate contamination is possibly the greatest threat to a public ground-water supply posed by a waste management unit. Incorporation of leachate collection, leak detection, and runoff control systems should further prevent any leachate from escaping into the ground water. Further discussion concerning liner systems, leachate collection and removal systems, and leak detection systems is included in Chapter 7, Section B–Designing and Installing Liners.

Control systems that separate storm-water run-on from any water that has contacted waste should also be considered. Proper control measures that redirect storm water to the supply source area should help alleviate this tendency. For additional information concerning storm water run-on and runoff control systems, refer to Chapter 6–Protecting Surface Water.

II. Buffer Zone Considerations

Many states require buffer zones between waste management units and other nearby land uses, such as schools. The size of a buffer zone often depends on the type of waste management unit and the land use of the surrounding areas. You should consult with state regulatory agencies and local advisory boards about buffer zone requirements before constructing a new unit or expanding an existing unit. A summary of state buffer zone requirements is included in the appendix at the end of this chapter.

Buffer zones provide you with time and space to mitigate situations where accidental releases might cause adverse human health or environmental impacts. The size of the buffer zone will be directly related to the intended benefit. These zones provide four primary benefits:

- Maintenance of quality of the surrounding ground water.
- Prevention of contaminant migration off site.
- Protection of drinking water supplies.
- Minimization of nuisance conditions perceived in surrounding areas.

Protection of ground water will likely be the primary concern for all involved parties. You should ensure that materials processed and disposed at your unit are isolated from ground-water resources. Placing your unit further from the water table and potential receptors, and increasing the number of physical barriers between your unit and the water table and potential receptors, provides for ground-water protection. It is therefore advised that, in addition to incorporating a liner system, where necessary, into a waste

Many nearby areas and land uses, such as schools, call for consideration of buffer zones.

management unit's design, you select a site where an adequate distance separates the bottom of a unit from the ground-water table. (See the appendix for a summary of these minimum separation distances.)[16] In the event of a release, this separation distance will allow for corrective action and natural attenuation to protect ground water.[17]

Additionally, in the event of an unplanned release, an adequate buffer zone will allow time for remediation activities to control contaminants before they reach sensitive areas. Buffer zones also provide additional protection for drinking water supplies. Drinking water supplies include ground water, individual and community wells, lakes, reservoirs, and municipal water treatment facilities.

Finally, buffer zones help maintain good relations with the surrounding community by protecting surrounding areas from any noise, particulate emissions, and odor associated with your unit. Buffer zones also help to prevent access by unauthorized people. For units located near property boundaries, houses, or historic areas, trees or earthen berms can provide a buffer to reduce noise and odors. Planting trees around a unit can also improve the aesthetics of a unit, obstruct any view of unsightly waste, and help protect property values in the surrounding community. When planting trees as a buffer, place them so that their roots will not damage the unit's liner or final cover.

A. Recommended Buffer Zones

You should check with state and local officials to determine what buffer zones might apply to your waste management unit. Areas for which buffer zones are recommended include property boundaries, drinking water wells, other sources of water, and adjacent houses or buildings.

Property boundaries. To minimize adverse effects on adjacent properties, consider incorporating a buffer zone or separation distance into unit design. You should consider planting trees or bushes to provide a natural buffer between your unit and adjacent properties.

Drinking water wells, surface-water bodies, and public water supplies. Locating a unit near or within the recharge area for sole source aquifers and major aquifers, coastal areas, surface-water bodies, or public water supplies, such as a community well or water treatment facility, also raises concerns. Releases from a waste management unit can pose serious threats to human health not only where water is used for drinking, but also where surface waters are used for recreation.

[16] A detailed discussion of technical considerations concerning the design and installation of liner systems, both in situ soil liners and synthetic liners, is included in Chapter 7, Section B – Designing and Installing Liners.

[17] Natural attenuation can be defined as chemical and biological processes that reduce contaminant concentrations.

Houses or buildings. Waste management units can present noise, odor, and dust problems for residents or businesses located on adjacent property, thereby diminishing property values. Additionally, proximity to property boundaries can invite increased trespassing, vandalism, and scavenging.

B. Additional Buffer Zones

There are several other areas for which to consider establishing buffer zones, including critical habitats, park lands, public roads, and historic or archaeological sites.

Critical habitats. These are geographical areas occupied by endangered or threatened species. These areas contain physical or biological features essential to the proliferation of the species. When designing a unit near a critical habitat, it is imperative that the critical habitat be conserved. A buffer zone can help prevent the destruction or adverse modification of a critical habitat and minimize harm to endangered or threatened species.[18]

Buffer zones can help protect endangered species and their habitats.

Park lands. A buffer between your unit and park boundaries helps maintain the aesthetics of the park land. Park lands provide recreational opportunities and a natural refuge for wildlife. Locating a unit too close to these areas can disrupt recreational qualities and natural wildlife patterns.

Public roads. A buffer zone will help reduce unauthorized access to the unit, reduce potential odor concerns, and improve aesthetics for travelers on the nearby road.

Historic or archaeological sites. A waste management unit located in close proximity to one of these sites can adversely impact the aesthetic quality of the site. These areas include historic settlements, battlegrounds, cemeteries, and Indian burial grounds. Also check whether a prospective site itself has historical or archaeological significance.

Historic sites call for careful consideration of buffer zones.

In summary, it is important to check with local authorities to ensure that placement of a new waste management unit or lateral expansion of an existing unit will not conflict with any local buffer zone criteria. You should also review any relevant state or tribal

[18] For the full text of the Endangered Species Act, visit the U.S. House of Representatives Internet Law Library Web site at <**uscode.house.gov/download.htm**>, under Title 16, Chapter 35.

regulations that specify buffer zones for your unit. For units located near any sensitive areas as described in this section, consider measures to minimize any possible health, environmental, and nuisance impacts.

III. Local Land Use and Zoning Considerations

In addition to location and buffer zone considerations, become familiar with any local land use and zoning requirements. Local governments often classify the land within their communities into areas, districts, or zones. These zones can represent different use categories, such as residential, commercial, industrial, or agricultural. You should consider the compatibility of a planned new unit or a planned lateral expansion with nearby existing and future land use, and contact local authorities early in the siting process. Local planning, zoning, or public works officials can discuss with you the development of a unit, compliance with local regulations, and available options. Local authorities might impose conditions for protecting adjacent properties from potential adverse impacts from the unit.

Addressing local land use and zoning issues during the siting process can prevent these issues from becoming prominent concerns later. Land use and zoning restrictions often address impacts on community and recreational areas, historical areas, and other critical areas. You should consider the proximity of a new unit or lateral expansion to such areas and evaluate any potential adverse effects it might have on these areas. For example, noise, dust, fumes, and odors from construction and operation of a unit could be considered a nuisance and legal action could be brought by local authorities or nearby property owners.

In situations where land use and zoning restrictions might cause difficulties in expanding or siting a unit, work closely with local authorities to learn about local land use and zoning restrictions and minimize potential problems. Misinterpreting or ignoring such restrictions can cause complications with intended development schedules or designs. In many cases, the use of vegetation, fences, or walls to screen your activities can reduce impacts on nearby properties. In addition, it might be possible to request amendments, rezonings, special exceptions, or variances to restrictions. These administrative mechanisms allow for flexibility in use and development of land. Learning about local requirements as early as possible in the process will maximize the time available to apply for variances or rezoning permits, or to incorporate screening into the plans for your unit.

IV. Environmental Justice Considerations

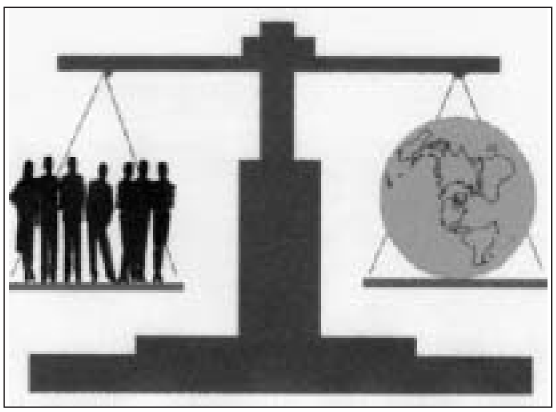
In the past several years, there has been growing recognition from communities and federal and state governments that some socioeconomic and racial groups might bear a disproportionate burden of adverse environmental effects from waste management activities. President Clinton issued Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, on February 11, 1994.[19] To be consistent with the definition of environmental justice in this executive order, you should identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of waste management pro-

[19] For the full text of Presidential Executive Order No. 12898 and additional information concerning environmental justice issues go to EPA's Web site at **<es.epa.gov/program/iniative/justice/justice.html>**.

grams, policies, and activities on minority and low-income populations.

One of the criticisms made by advocates of environmental justice is that local communities endure the potential health and safety risks associated with waste management units without enjoying any of the economic benefits. During unit siting or expansion, address environmental justice concerns in a manner that is most appropriate for the operations, the community, and the state or tribal government.

You should look for opportunities to minimize environmental impacts, improve the surrounding environment, and pursue opportunities to make the waste management



facility an asset to the community. When planning these opportunities, it is beneficial to maintain a relationship with all involved parties based on honesty and integrity, utilize cross-cultural formats and exchanges, and recognize industry, state, and local knowledge of the issues. It is also important to take advantage of all potential opportunities for developing partnerships.

Examples of activities that incorporate environmental justice issues include tailoring activities to specific needs; providing interpreters, if appropriate; providing multilingual materials; and promoting the formation of a community/state advisory panel.

Tailor the public involvement activities to the specific needs. Good public involvement programs are site-specific—they take into account the needs of the facility, neighborhood, and state. There is no such thing as a "one-size-fits-all" public involvement program. Listening to each other carefully will identify the specific environmental justice concerns and determine the involvement activities most appropriate to address those needs.

Provide interpreters for public meetings. Interpreters can be used to ensure the information is exchanged. Provide interpreters, as needed, for the hearing impaired and for any languages, other than English, spoken by a significant percentage of the audience.

Provide multilingual fact sheets and other information. Public notices and fact sheets should be distributed in as many languages as necessary to ensure that all interested parties receive necessary information. Fact sheets should be available for the visually impaired in the community on tape, in large print, or braille.

Promote the formation of a community/state advisory panel to serve as the voice of the community. The Louisiana Department of Environmental Quality, for example, encourages the creation of environmental justice panels comprised of community members, industry, and state representatives. The panels meet monthly to discuss environmental justice issues and find solutions to any concerns identified by the group.

Considering the Site Activity List

General Siting Considerations

❑ Check to see if the proposed unit site is:

— In a 100-year floodplain.

— In or near a wetland area.

— Within 200 feet of an active fault.

— In a seismic impact zone.

— In an unstable area.

— Close to an airport.

— Within a wellhead protection area.

❑ If the proposed unit site is in any of these areas:

— Design the unit to account for the area's characteristics and minimize the unit's impacts on such areas.

— Consider siting the unit elsewhere.

Buffer Zone Considerations

(Note that many states require buffer zones between waste management units and other nearby land uses.)

❑ Check to see if the proposed unit site is near:

— The ground-water table.

— A property boundary.

— A drinking water well.

— A public water supply, such as a community well, reservoir, or water treatment facility.

— A surface-water body, such as a lake, stream, river, or pond.

— Houses or other buildings.

— Critical habitats for endangered or threatened species.

— Park lands.

— A public road.

— Historic or archaeological sites.

❑ If the proposed unit site is near any of these areas or land uses, determine how large a buffer zone, if any, is appropriate between the unit and the area or land use.

Considering the Site Activity List (cont.)

Local Land Use and Zoning Considerations

- ❑ Contact local planning, zoning, and public works agencies to discuss restrictions that apply to the unit.
- ❑ Comply with any applicable restrictions, or obtain the necessary variances or special exceptions.

Environmental Justice Considerations

- ❑ Determine whether minority or low-income populations would bear a disproportionate burden of any environmental effects of the unit's waste management activities.
- ❑ Work with the local community to devise strategies to minimize any potentially disproportionate burdens.

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Appendix: State Buffer Zone Considerations

The universe of industrial wastes and unit types is broad and diverse. States have established various approaches to address location considerations for the variety of wastes and units in their states. The tables below summarize the range of buffer zone restrictions and most common buffer zone values specified for each unit type by some states to address their local concerns. The numbers in the tables are not meant to advocate the adoption of a buffer zone of any particular distance; rather, they serve only as examples of restrictions states have individually developed.

- Surface impoundments. Restrictions with respect to buffer zones vary among states. In addition, states allow exemptions or variances to these buffer zone restrictions on a case-by-case basis. Table 1 presents the range of values and the most common value used by states for each buffer zone category.

Table 1
State Buffer Zone Restrictions for Surface Impoundments

Buffer Zone Category	Range of Values—minimum distance (number of states with this common value)		Most Common Value (number of states with this common value)	
Groundwater Table	1 to 15 feet	(4)	5 feet	(2)
Property Boundaries	100 to 200 feet	(4)	100 feet	(2)
Drinking Water Wells	1,200 to 1,320 feet	(2)	1,200 feet 1,320 feet	(1) (1)
Public Water Supply	500 to 1,320 feet	(4)	1,320 feet	(2)
Surface Water Body	100 to 1,320 feet	(4)	100 feet	(2)
Houses or Buildings	300 to 1,320 feet	(4)	1,320 feet	(2)
Roads	1,000 feet	(1)	1,000 feet	(1)

- Landfills. Table 2 presents the range of values and the most common state buffer zone restrictions for landfills.

Table 2
State Buffer Zone Restrictions for Landfills

Buffer Zone Category	Range of Values—minimum distance (number of states with this common value)		Most Common Value (number of states with this common value)	
Groundwater Table	1 to 15 feet	(12)	5 feet	(4)
Property Boundaries	20 to 600 feet	(14)	100 feet	(7)
Drinking Water Wells	500 to 1,320 feet	(9)	500 feet 600 feet 1,200 feet	(2) (2) (2)
Public Water Supply	400 to 5,280 feet	(13)	1,200 feet	(3)
Surface Water Body	100 to 2,000 feet	(20)	100 feet 1,000 feet	(5) (5)
Houses or Buildings	200 to 1,320 feet	(14)	500 feet	(7)
Roads	50 to 1,000 feet	(8)	1,000 feet	(5)
Park Land	1,000 to 5,280 feet	(7)	1,000 feet	(4)
Fault Areas	200 feet	(2)	200 feet	(2)

- Waste Piles. Table 3 presents the state buffer zone restrictions for waste piles. Of the four states with buffer zone restrictions, only two states specified minimum distances.

Table 3
State Buffer Zone Restrictions for Waste Piles

Buffer Zone Category	Range of Values-minimum distance (number of states with this common value)		Most Common Value (number of states with this common value)	
Groundwater Table	4 feet*	(1)	4 feet*	(1)
Property Boundaries	50 feet	(1)	50 feet	(1)
Surface Water Body	50 feet	(1)	50 feet	(1)
Houses or Buildings or Recreational Area	200 feet	(1)	200 feet	(1)
Historic Archeological Site or Critical Habitat	Minimum distance not specified	(1)	Minimum distance not specified	(1)

* If no liner or storage pad is used, then this state requires four feet between the waste and the seasonal high water table.

- Land Application.[20] Table 4 presents the range of values and the most common state buffer zone restrictions for land application.

Table 4
State Buffer Zone Restrictions for Land Application

Buffer Zone Category	Range of Values-minimum distance (number of states with this common value)		Most Common Value (number of states with this common value)	
Groundwater Table	4 to 5 feet	(3)	4 feet 5 feet	(1) (1)
Property Boundaries	50 to 200 feet	(4)	50 feet	(2)
Drinking Water Wells	200 to 500 feet	(2)	200 feet 500 feet	(1) (1)
Public Water Supply	300 to 5,280 feet	(3)	300 feet 1,000 feet 5,280 feet	(1) (1) (1)
Surface Water Body	100 to 1,000 feet	(5)	100 feet	(2)
Houses or Buildings	200 to 3,000 feet	(6)	300 feet 500 feet	(2) (2)
Park Land	2,640 feet	(1)	2,640 feet	(1)
Fault Areas	200 feet	(1)	200 feet	(1)
Max. Depth of Treatment	5 feet	(1)	5 feet	(1)
Pipelines	25 feet	(1)	25 feet	(1)
Critical Habitat	No minimum distance set	(2)	No minimum distance set	(2)
Soil Conditions	Not on frozen, ice or snow covered, or water saturated soils	(1)	Not on frozen, ice or snow covered, or water saturated soils	(1)

[20] In the review of state regulations performed to develop Table 5, it was not possible to distinguish between units used for treatment and units where wastes are added as a soil amendment. It is recommended that you consult applicable state agencies to determine which buffer zone restrictions are relevant to your land application unit.

Based on the review of state requirements, Table 5 presents the most common buffer zones restrictions across all four unit types.

Table 5
Common Buffer Zone Restrictions Across All Four Unit Types

Buffer Zone Category (total number of states for all unit types)		Most Common Values (number of states with this common value)	
Groundwater Table	(20)	4 feet 5 feet	(4) (4)
Property Boundaries	(23)	50 feet 100 feet	(8) (5)
Drinking Water Wells	(13)	500 feet	(3)
Public Water Supply	(20)	1,000 feet 1,200 feet 5,280 feet	(3) (3) (3)
Surface Water Body	(30)	100 feet 200 feet 1,000 feet	(5) (5) (7)
Houses or Buildings	(25)	500 feet	(9)